

REINFORCEMENT MAGNITUDE AND PAUSING ON PROGRESSIVE-RATIO SCHEDULES

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Rats responded under progressive-ratio schedules for sweetened milk reinforcers; each session ended when responding ceased for 10 min. Experiment 1 varied the concentration of milk and the duration of postreinforcement timeouts. Postreinforcement pausing increased as a positively accelerated function of the size of the ratio, and the rate of increase was reduced as a function of concentration and by timeouts of 10 s or longer. Experiment 2 varied reinforcement magnitude within sessions (number of dipper operations per reinforcer) in conjunction with stimuli correlated with the upcoming magnitude. In the absence of discriminative stimuli, pausing was longer following a large reinforcer than following a small one. Pauses were reduced by a stimulus signaling a large upcoming reinforcer, particularly at the highest ratios, and the animals tended to quit responding when the past reinforcer was large and the stimulus signaled that the next one would be small. Results of both experiments revealed parallels between responding under progressive-ratio schedules and other schedules containing ratio contingencies. Relationships between pausing and magnitude suggest that ratio pausing is under the joint control of inhibitory properties of the past reinforcer and excitatory properties of stimuli correlated with the upcoming reinforcer, rather than under the exclusive control of either factor alone.

Key words: postreinforcement pause, reinforcer magnitude, progressive-ratio schedules, ratio schedules of reinforcement, timeout from reinforcement, inhibitory effects of reinforcement, lever press, rats

Although research on reinforcement schedules has declined over the years, some fundamental questions remain unanswered (Zeiler, 1984). A case in point is the phenomenon of postreinforcement pausing on fixed-ratio (FR) schedules and, in particular, the role played by the magnitude of the reinforcing stimulus (Bonem & Crossman, 1988). One view is that pausing is controlled by excitatory properties of the upcoming reinforcer (e.g., Shull, 1979). Increases in the magnitude of the reinforcer should, therefore, reduce the duration of pausing. Alternatively, some writers have suggested that pausing reflects inhibitory aftereffects of the previous reinforcer (Harzem & Harzem, 1981). It follows that increases in the magnitude of the reinforcer should increase pausing.

Experiments on the pause-magnitude relationship have not provided consistent evi-

dence for either view. Powell (1969), for example, found that pausing was inversely related to reinforcement magnitude, whereas Lowe, Davey, and Harzem's (1974) results were the opposite; pausing increased as the magnitude was increased. To complicate matters further, Perone, Perone, and Baron (1987) could not detect a relationship between pausing and magnitude, once the minimal magnitude needed to maintain responding had been reached.

In an effort to reconcile these contradictory results and interpretations, Perone et al. (1987) proposed that pausing might best be regarded as the product of competing excitatory and inhibitory influences rather than the exclusive consequence of either alone. The inverse pause-magnitude relationship in Powell's (1969) experiment resulted from a procedure in which the different magnitudes were correlated with different colored lights. These discriminative stimuli provided a source of excitatory control to counteract any inhibitory aftereffects of the larger magnitudes. By comparison, the positive relationship in Lowe et al.'s (1974) experiment came from a procedure in which different magnitudes were varied randomly in the absence of correlated stimuli. Inhibitory factors could predominate because the upcoming magnitudes were unpredictable.

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Finally, the steady-state design of Perone *et al.*'s (1987) experiment may have been responsible for the failure to observe a pause-magnitude relationship (either positive or negative). Procedures that expose the subject to the same magnitude for many sessions work against dominance by either inhibitory or excitatory influences. Although inhibitory after-effects increase with increased magnitudes, excitatory effects increase as well, because the particular magnitude is accurately predicted by stimuli correlated with the schedule itself. Another consequence of extended training is that control by the schedule reduces control by unique features of the reinforcing event (Kling & Schrier, 1971; Morse & Kelleher, 1977). Perone *et al.* noted in this regard that experiments showing magnitude-pause relationships (either positive or negative) more often than not have involved weak degrees of schedule control—for example, schedules producing ratio strain (Hodos & Kalman, 1963) or schedules in which a series of changing magnitudes is contained within the same session (Lowe *et al.*, 1974).

The question of magnitude-pause relationships was pursued in the present research in the context of progressive-ratio (PR) schedules of reinforcement. The special feature of this type of schedule is that the response requirement increases from ratio to ratio (e.g., five responses for the first, 10 for the second, etc.); each session ends when the subject stops responding (the so-called breaking point). These two considerations—increasing ratios and eventual extinction—make the PR schedule an interesting vehicle for studying changes in ratio pausing as schedule control weakens. The original work by Hodos (1961) and Hodos and Kalman (1963) showed that the breaking point increases as a function of the reinforcement magnitude (in their study, the concentration and volume of liquid food). But the picture of magnitude-pause relations is incomplete in this and subsequent experiments (e.g., Keesey & Goldstein, 1968; Thomas, 1974) because these analyses relied almost exclusively on the breaking-point measure—that is, the very last pause of the session, which is the part of the schedule when schedule control is weakest. Quantitative data on pausing at earlier points have not been reported to our knowledge (some studies have included cumulative records, however).

EXPERIMENT 1

Pause data were collected on a ratio-by-ratio basis, and two variables were manipulated along the lines of Perone *et al.*'s (1987) fixed-ratio experiment: the concentration of the sweetened milk that followed completion of each ratio and the duration of a subsequent period of timeout from responding. If pausing depends on inhibitory properties of the reinforcers, the onset of responding should be delayed as a function of increasing magnitudes. Inhibitory effects should be attenuated, however, by postreinforcement timeouts, because such effects are expected to dissipate with the passage of time. If, on the other hand, excitatory properties of the reinforcers play the dominant role, pausing should decrease as a function of the magnitude. Moreover, the timeouts should not influence the inverse magnitude-pause relationship insofar as pausing is under the exclusive control of stimuli correlated with the upcoming reinforcer.

METHOD

Subjects

Four male albino Sprague-Dawley derived rats were approximately 10 months old at the start of the experiment. They had previously served in preliminary experiments with schedules and timeout procedures similar to the present ones. Each animal was housed in an individual cage under continuous illumination with free access to water. Food deprivation was accomplished by scheduling 1-hr feeding periods shortly after the experimental sessions (Hurwitz & Davis, 1983). Sessions were conducted 5 to 6 days per week.

Apparatus

Single-lever rodent chambers (Grason-Stadler, E3125; 29 cm by 24 cm by 19 cm) were enclosed in sound-attenuating ventilated chests. The lever, which required a minimum force of 40 g (approximately 0.4 N) to operate, was centered on the front wall, 9.5 cm above the grid floor. Directly below was a cylindrical opening into which a 0.05 mL dipper could be raised. General illumination was provided by a 3-W lamp mounted behind a translucent white screen on the right wall. Extraneous sounds were masked by white noise and the sound of the ventilating fan. Programming and recording equipment was in an adjacent room.

Procedure

Lever pressing was reinforced according to a PR schedule with a step size of five. Each session began with delivery of a reinforcer upon completion of five responses. The second reinforcer required 10 responses, the third 15, and so on. The schedule continued until 10 min had elapsed without a response (the breaking point). The reinforcer was a solution of sweetened condensed milk in tap water with milk concentrations of either 30%, 50%, or 70% by volume. During the 3-s reinforcement period, the dipper containing the milk was raised, a tone replaced the background white noise, and the lever was deactivated.

Timeouts of different durations separated the end of the reinforcement cycle and the reactivation of the lever for the next ratio. During the timeouts, the chamber light and masking noise (both normally on during the session) were turned off, and each lever press reset the timer that controlled the duration; as a consequence, responding during the timeout periods was rare. Five timeout durations were studied: 0, 5, 10, 20, and 30 s. A given duration was in effect for the entire session; the durations changed from day to day in a haphazard order with the restriction that each duration appeared once within each 5-day block.

The experiment was conducted in three phases each with a different milk concentration. During the first phase, the concentration was set at 50%, the value used during preliminary training. After 40 sessions (i.e., eight sessions at each timeout duration), the concentration was reduced to 30%, and 50 additional sessions were conducted (the two additional blocks allowed adaptation to the new concentration). During the final phase, 50 sessions were conducted with the 70% concentration.

RESULTS

Postreinforcement pauses and run times were recorded to the nearest second. Pauses were measured from the end of the timeout that followed the reinforcement cycle to the first response of the upcoming ratio. Run times, used to calculate running rates, were measured from the first to the last response within a ratio. Analyses were based on the last eight blocks of each concentration condition. Performances, as indicated by daily breaking points, were stable when conditions were changed (in all

cases, the difference between the medians of Blocks 1 through 4 and 5 through 8 was less than 20% of the median for Blocks 1 through 8).

Pause data for each rat are summarized in Figure 1. The graphs are organized in terms of the three variables of the experiment: (a) increasing ratios within the schedule, (b) timeout durations, and (c) reinforcer concentrations. The values for each ratio are the medians for the eight sessions under each timeout-concentration combination; to simplify the presentation, pairs of ratios were combined (e.g., FR 5 and FR 10). To accommodate the wide range of latency values (from 1 s to 600 s), performances are plotted on a logarithmic scale.

The most general finding is that pausing increased as a positively accelerated function of ratio size (Figure 1). Latencies were brief for a good part of the progression, mainly in the range from 1 s to 10 s, and subsequent increases to the final breaking point value were abrupt, usually spanning no more than the last four or five ratios. Also apparent is that pause duration and reinforcer concentration were inversely related; that is, latencies increased when the concentration was reduced from 50% to 30% and decreased when the concentration was increased to 70% (the final value of the experiment). The only deviation from this pattern was R16, whose durations at 50% and 70% were about the same.

The results also provided evidence that the postreinforcement timeouts reduced pausing. This relationship may be seen most clearly in the data from R14 and R15 by comparing performance at the two extremes (0 s vs. 30 s). In the absence of the timeouts (0-s condition), their latencies increased in a more or less linear fashion until the final few ratios. Under the timeout conditions, by comparison, the brief latencies that characterized the start of the schedule were maintained further into the progression, and the final acceleration to the breaking point was more abrupt.

Figure 2 summarizes breaking points for the different concentration and timeout conditions. The first panel for each animal shows the conventional breaking point measure: the highest ratio attained before the session ended (the first pause exceeding 10 min). The other two panels show results when more stringent pause criteria are applied: The highest ratio before a pause exceeded 10 s (Panel 2) and the highest

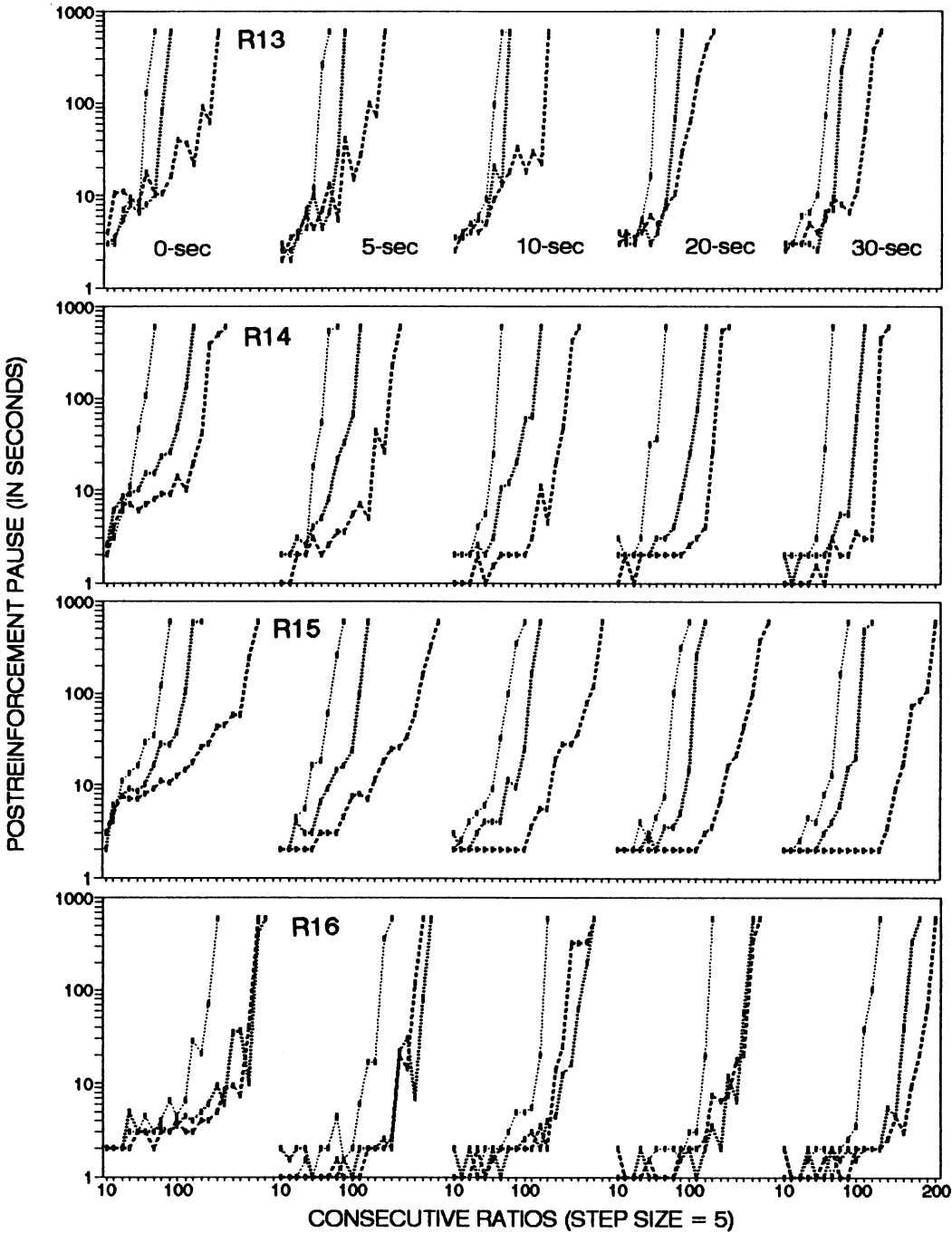


Fig. 1. Experiment 1: Pause durations as a function of ratio size (x axis), timeout duration (the five groups of functions: 0, 5, 10, 20, and 30 s), and reinforcer concentration (the functions designated by different dotted lines: light = 30%; intermediate = 50%; dark = 70%). Note that latencies are scaled logarithmically and that each set of functions depicts a new series of consecutive ratios.

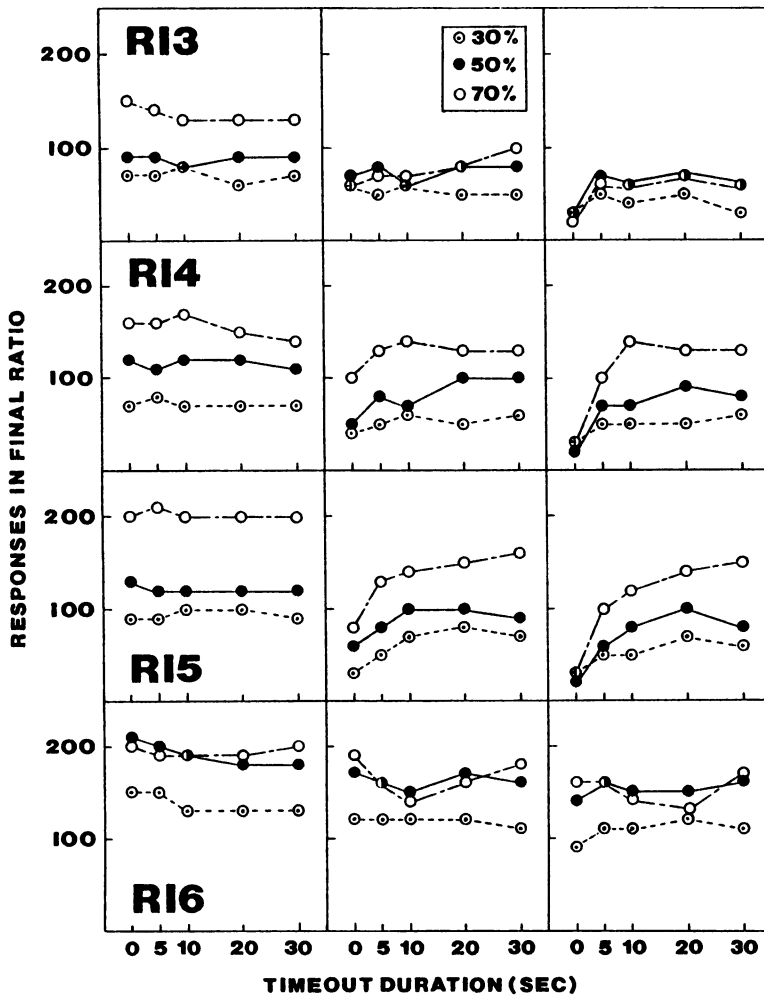


Fig. 2. Experiment 1: The point in the progressive-ratio schedule when the first pause of a specified duration occurred (breaking points). Three criteria are shown: 10 min (the duration that ended the session; Panel 1), 10 s (Panel 2), and 5 s (Panel 3). Values are plotted as a function of reinforcer concentration and timeout duration.

ratio before a pause exceeded 5 s (Panel 3). Taken together, the three criteria provide measures of concentration and timeout effects under increasing levels of schedule control. Thus, the 10-min criterion identifies the point in the progression when control was weakest—just before the response extinguished. The 5- and 10-s criteria, by comparison, index performances when schedule control was stronger—the point of transition from maximal control (the initial limbs of the pause-ratio functions in Figure 1) to progressively weaker control (the rapid acceleration of latencies to the final breaking point).

The results in Figure 2 provide evidence that control by the schedule determined the nature of the interaction between concentration and timeout. Under conditions of weak schedule control (Panel 1; the end of the schedule), performances depended exclusively on the concentration; increased concentration prolonged responding (delayed the final criterion pause) regardless of timeout duration. Under conditions of increased schedule control (Panels 2 and 3), concentration effects were more likely to depend on timeout duration. For 3 of the 4 animals (R16 is the exception), the criterion pause was attained earlier when the

timeouts were omitted (0 s) or after very brief timeouts (5 s) than when the timeouts were longer (10, 20, or 30 s).

By comparison with the pause and breaking-point measures, running rates were not as consistently influenced by the experimental variables. Figure 3 shows that rates declined within sessions. In most cases, the decline was gradual, and sustained responding continued until the very highest ratios of the schedule. Responding often was erratic at the end, however (note that the session continued until 10 min had elapsed without a response); because average rates might be misleading, rates of less than 20 responses per minute are not included in the functions. There was some indication that the higher concentrations were associated with higher rates, most clearly in the case of R14 for all of the timeout conditions and R16 for the 30-s timeout. Finally, contrary to outcomes with the other measures, running rates were more or less independent of the timeouts.

DISCUSSION

The progressive-ratio schedule has not been subjected to the same scrutiny as the much-studied fixed-ratio and variable-ratio (VR) schedules. Although all three schedules deliver reinforcers on the basis of response output, they differ in the way that ratios of different values are integrated into the schedule. FR and VR schedules hold the value constant, usually within entire sessions, and effects of ratios of different sizes must be studied through steady-state comparisons of different values. The progressive schedule, by comparison, imposes the different ratios in an ascending order within each session, and a steady-state comparison of performance under the different ratios must be based on combining ratios from a series of such sessions. Given this difference, it is of interest to determine whether the variables of the present study (ratio size, reinforcer magnitude, timeout from responding) have common influences. A review of experiments on FR and VR reinforcement indicates that similarities are much more common than differences. The characteristic finding has been that pausing increased as a positively accelerated function of ratio size. Previous investigators of PR schedules did not attempt quantitative analyses; the published cumulative records, however, suggest a similar pattern (Hodos & Kalman, 1963; Thomas, 1974). Positively accelerated pause-ratio relationships also have

been found with FR and VR schedules (Blakely & Schlinger, 1988; Felton & Lyon, 1966; Pridle-Higson, Lowe, & Harzem, 1976; Schlinger, Blakely, & Kaczor, 1990). The rate of increase with these other schedules appears to be logarithmic (e.g., Felton & Lyon, 1966), whereas acceleration within the present PR schedule was considerably greater. This difference, most likely, is a consequence of the increasing strain as the PR schedule advances to larger and larger values within each session. Consistent with such an interpretation is the finding that procedures that trained subjects for entire sessions at a given value before increasing the ratio produced intermediate pause-ratio functions (Powell, 1968).

The further finding was that increases in the magnitude of the reinforcers reduced pausing and attenuated the slopes of the pause-ratio functions. Studies with FR and VR schedules have reported similar results, that is, steeper pause-ratio slopes with smaller magnitudes (Blakely & Schlinger, 1988; Powell, 1969). Conclusions about the role of magnitude must be somewhat tentative insofar as only one sequence of concentrations was examined in the present study (50%, 30%, 70%). Also, note that not every experiment with ratio schedules has observed inverse pause-magnitude relationships. Perone *et al.* (1987) suggested that negative results may be linked to procedures that give subjects extended exposure to the ratios and concentrations under study (steady-state designs). The orderly relationships of the present study are contrary to such an interpretation (the subjects had extensive experience with the PR schedule and the concentrations).

The observed effects of the postreinforcement timeouts on pausing have counterparts in two experiments with FR schedules (Mazur & Hyslop, 1982; Perone *et al.*, 1987). Both compared a single timeout duration (30 s) with a control condition (0 s) and found, as in the present study, that the timeouts attenuated pausing. Results from intermediate durations (within the 30-s range) suggest that effects may be concentrated in the initial part of the timeout period.

Finally, some parallels involving running rates should be noted. Although response rates decreased as the ratio size increased, the changes were not influenced consistently by either the magnitude or timeout variables. Research with FR schedules also revealed that

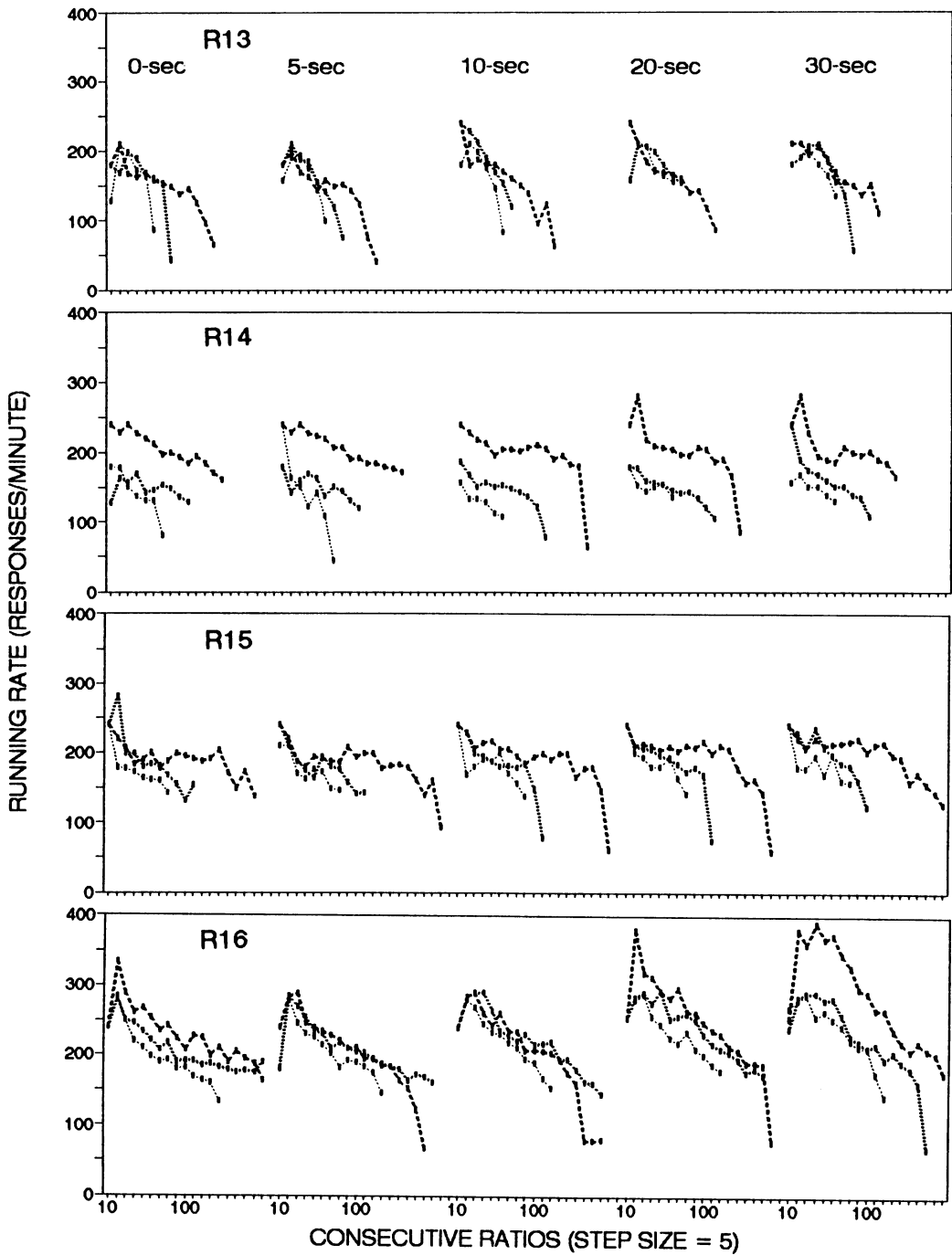


Fig. 3. Experiment 1: Running rates as a function of ratio size (x axis), timeout duration (the five groups of functions: 0, 5, 10, 20, and 30 s), and reinforcer concentration (the functions designated by different dotted lines: light = 30%; intermediate = 50%; dark = 70%). Note that latencies are scaled logarithmically and that each set of functions depicts a new series of consecutive ratios.

running rates are inversely related to ratio size and are uninfluenced by timeouts (Mazur & Hyslop, 1982). The picture for VR schedules is less clear, in that the rate-ratio relationship is not as regular and there is indication that higher magnitudes may lead to increased rates (Blakely & Schlinger, 1988; Schlinger *et al.*, 1990).

EXPERIMENT 2

The interpretation laid out by Perone *et al.* (1987) was that the postreinforcement pause reflects the resolution of a competition between conditioned excitatory factors that reduce pausing and unconditioned inhibitory factors that increase pausing. The results of Experiment 1 are consistent with such a view, in that (a) increased magnitude led to reduced pausing (the steady-state procedure allowed the prevailing magnitude to be signaled by excitatory cues originating in the schedule), (b) postreinforcement timeouts reduced pausing (the timeouts allowed inhibitory effects to dissipate), and (c) reinforcement-magnitude effects increased as the breaking point was approached (features of the reinforcing stimulus assumed greater control as schedule control decreased).

Experiment 2 pursued further tests of the competition account using a novel procedure developed by Perone and Courtney (1992). Their method is designed to pit inhibitory and excitatory factors against each other by presenting different magnitudes in an irregular order within each session. Under the mixed-schedule condition, the upcoming magnitudes are unsignaled; therefore, only the inhibitory influences of the past reinforcer can be expressed. Under the multiple-schedule condition, by comparison, the upcoming magnitudes are correlated with explicit discriminative stimuli, thereby allowing responding to be influenced by excitatory factors. Performances under the multiple-schedule procedure should reveal the competition between inhibitory and excitatory influences. Specifically, when a previous small magnitude (low inhibition) is followed by a stimulus that predicts a large upcoming magnitude (high excitation), pausing should be briefer than when a previous large magnitude (high inhibition) is followed by a stimulus predicting an upcoming small one (low excitation).

METHOD

Three additional rats were trained on a PR schedule with a step size of two and an extinction criterion of 5 min. The smaller step size increased the number of ratios in each session (*cf.* Hodos & Kalman, 1963), thereby facilitating scheduling of a varied sequence of small and large magnitudes, and the shorter extinction criterion avoided unnecessary prolongation of the session. The apparatus was the same as for Experiment 1.

The magnitude of the reinforcers was manipulated within sessions by varying the number of presentations of the 30% milk concentration that followed completion of each ratio. Two magnitudes occurred in an irregular sequence within each session: either one presentation of the dipper for 3 s (small) or three presentations for 3 s each (large; this increased the total duration of the reinforcement period to 10 s). The sequence was arranged to include equal numbers of the four orders of past and upcoming reinforcers (*i.e.*, small-small, small-large, large-small, and large-large).

Following preliminary training, observations continued for 16 sessions (mixed condition). For the subsequent 40 to 50 sessions, the upcoming magnitude was signaled by the cue lights to the left and right of the lever (multiple condition). For 2 animals, the left light blinked when the next reinforcer was large and the right light was on continuously when the next reinforcer was small. Stimulus-magnitude correlations were reversed for the 3rd subject.

RESULTS

Figure 4 summarizes pausing during the mixed and multiple phases of Experiment 2. The figure is organized to show latencies at three points within the progression of ratios: at the start of the session, midway in the session, and at the end (*i.e.*, the first four ratios, the middle two to five ratios, the number of which depended on the total number of ratios completed, and the last four ratios). At each of these junctures, performances are depicted as a function of the magnitude of the previous reinforcer and the magnitude of the upcoming reinforcer. The points in the figure are the medians of 32 latencies (middle = 20 to 32 latencies) collected over the last 8 days of each phase.

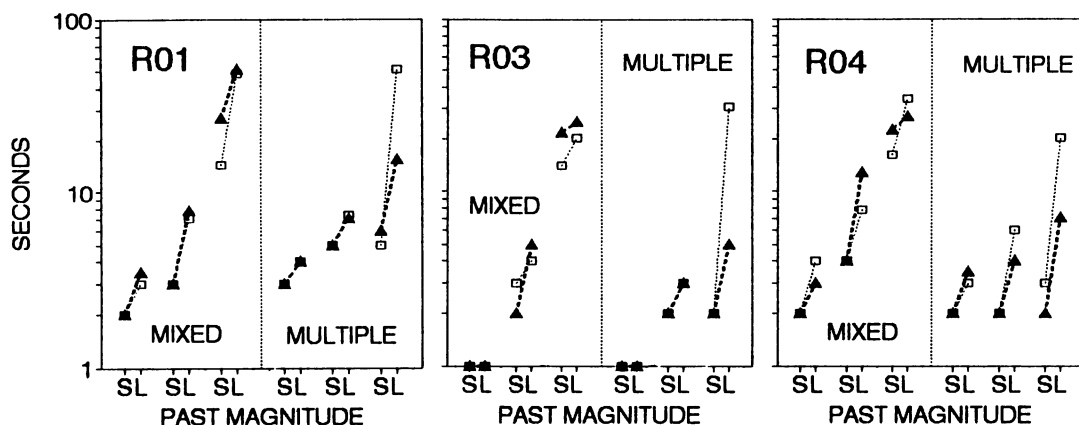


Fig. 4. Experiment 2: Pause durations under the mixed and multiple conditions as a function of past and upcoming reinforcer magnitudes. Data are plotted separately for the mixed and multiple conditions. Open squares depict data from pauses at the beginning of ratios that ended with the smaller reinforcer; filled triangles depict those from ratios that ended with the larger reinforcer.

Results from the mixed condition generally were similar to those from Experiment 1. Pausing increased as the schedule advanced, and the durations were longer following the large magnitude than the small one; this effect became more pronounced at the higher ratios. By comparison, effects of the upcoming magnitude on pausing were unsystematic.

Introduction of the discriminative stimuli under the multiple condition produced a characteristic interaction that involved the sequence of reinforcers and the size of the ratios. At the beginning and middle of the schedule, pauses tended to follow the same pattern as for the mixed condition: They were longer following the large than the small reinforcer, and influences of the upcoming reinforcer either were absent (R01, R03) or relatively small (R04). The picture changed at the end of the schedule. Although pausing continued to be more prolonged following a large than a small reinforcer, this effect was considerably smaller when the upcoming reinforcer was large than when it was small (compare the slopes of the light and dark lines in Figure 4). Following the procedures of Experiment 1, the results are plotted on a logarithmic scale. Therefore, the interaction just described is considerably more extreme when plotted arithmetically.

A noteworthy feature of the results in Figure 4 is the difference between the mixed- and multiple-schedule conditions. Although exceptions may be seen, pauses under the multiple schedule tended to be shorter than under the

comparable mixed condition. This effect is pronounced for the data from the end of the schedule, particularly when a small reinforcer had just been received. Under the mixed schedule, pauses at this point averaged 10 s or more. By comparison, multiple-schedule pauses were in the range of 1 or 2 s for Subjects R03 and R04 and did not exceed 5 or 6 s for R01. Also apparent is that the upcoming reinforcer played a minor role at best—pauses tended to be as brief when the stimulus signaled that the next reinforcer would be small as when the stimulus indicated that it would be large.

Information about running rates and breaking points during the terminal eight sessions is provided in Table 1. Running rates declined as a function of the size of the ratio, but the magnitude sequence did not have systematic influences. The breaking-point data indicate that although the multiple schedule produced shorter pauses, the mixed schedule tended to maintain responding to higher ratios. The data in the right part of Table 1 show the magnitude sequence that was in effect when the animal quit responding (the values give the number of sessions of each type; total = 8). Performances under the mixed condition were irregular; if magnitude had any effect, it was in favor of a weak tendency for the extinction criterion to be met following a large reinforcer (R01, R03). Performances under the multiple condition were more consistent. Along the lines of the pause data, the most frequent combination when responding extinguished was one

Table 1

Experiment 2: Median running rates (responses per minute). Values are from the last eight sessions of the mixed and multiple conditions at three points in the schedule (beginning, middle, end). Results are grouped in terms of past and upcoming magnitudes (small-small, large-small, small-large, large-large). Also shown are median breaking points and the number of sessions that each magnitude combination was in effect when the animal quit responding (total = 8).

Rat	Schedule	Ratios	Running rates				Breaking point	Last ratio			
			S-S	L-S	S-L	L-L		S-S	L-S	S-L	L-L
R01	Mixed	Beginning	141	149	151	163	132	2	1	1	4
		Middle	106	108	121	111					
		End	116	99	109	101					
	Multiple	Beginning	150	150	160	155	119	1	7	—	—
		Middle	118	112	123	110					
		End	87	85	87	93					
R03	Mixed	Beginning	212	210	214	224	141	—	3	3	2
		Middle	168	161	160	168					
		End	125	126	130	131					
	Multiple	Beginning	187	201	216	210	110	2	6	—	—
		Middle	167	171	177	179					
		End	145	153	149	147					
R04	Mixed	Beginning	113	127	127	128	101	1	1	3	3
		Middle	80	81	84	85					
		End	74	70	72	77					
	Multiple	Beginning	121	133	156	145	92	—	8	—	—
		Middle	94	101	92	94					
		End	87	93	89	97					

in which a large reinforcer had been delivered and the stimulus signaled that the upcoming reinforcer would be small.

DISCUSSION

Results from the highest ratios of the PR schedule of Experiment 2 were similar to those reported by Perone and Courtney (1992) in an experiment with pigeons rather than rats under FR rather than PR schedules. In both studies, pausing under the mixed condition depended exclusively on the previous reinforcer, and magnitude effects were inhibitory in that pauses were longer following the larger magnitude. The multiple condition of both experiments provided evidence of the excitatory properties of the upcoming reinforcer. If the stimulus signaled that it would be large, the pause was considerably shorter than when the stimulus signaled that it would be small.

A finding not reported by Perone and Courtney (1992) involves the differences between the mixed and multiple schedules. The pauses during multiple-schedule training not only were generally shorter but also tended to be the same for the small-small and the small-large sequences. Shorter pauses in the latter

case are not unexpected—the multiple-schedule stimulus is the one correlated with a large upcoming reinforcer. The finding of shorter pauses when the stimulus signals a small upcoming reinforcer is more difficult to explain.

One possible account is based on the observation that the procedures included features of chained schedules. Completion of each ratio in the PR schedule not only produced the reinforcer for that ratio (either large or small) but also allowed access to the next ratio and its reinforcer. The multiple-schedule stimuli, therefore, had the potential to serve as conditioned reinforcers that would reduce the extent of pausing. Consider an animal that pauses in the presence of the stimulus correlated with the small upcoming reinforcer. Although the discriminative properties of the stimulus support pausing, responding under these circumstances bears a 50-50 chance of producing the stimulus correlated with the large reinforcer—a contingency that supports responding. Under the mixed-schedule condition, by comparison, the absence of the correlated stimuli prohibits such an effect.

Without data, the above account must be largely speculative. One test would be to use

procedures that vary the probabilities of the concentrations within the schedule. A 25-75 small-large distribution, for example, should enhance the reinforcing properties of the large-reinforcer stimulus and increase the difference between the mixed and multiple schedules. By the same token, a 75-25 distribution of large and small reinforcers should reduce schedule differences.

GENERAL DISCUSSION

The present results, along with those of Perone et al. (1987) and Perone and Courtney (1992), support an account of pause-magnitude relations in terms of competing sources of control: control by the inhibitory aftereffects of the past reinforcer that lead to direct relationships and control by the excitatory properties of the upcoming reinforcer that lead to inverse ones. Perone and Courtney explained how a competition account can be used to organize the otherwise contradictory literature on pause-magnitude relations; the interested reader is referred to their cogent review for the details.

One matter that warrants further discussion concerns the need for a concept of inhibition in the analysis. This is certainly not a new issue. For example, Skinner (1938) in an early discussion asked whether extinction can be accounted for without recourse to hypothetical inhibitory processes. He reached the conclusion that weakening of performance is better viewed as no more than the depletion of a previously established reserve; others (e.g., Rescorla, 1975) also have viewed the evidence for an inhibitory process in extinction as less than compelling.

In discussing their experiment, Perone and Courtney (1992) also raised the possibility that pause-magnitude relations might be accounted for exclusively in excitatory terms. When magnitude is varied in the absence of explicit discriminative stimuli (the mixed condition of their experiment and the present Experiment 2; see also Harzem & Harzem, 1981), the irregular sequence is intended to exclude stimuli correlated with the upcoming magnitude. But whether this goal was attained may be questioned on the grounds that the reinforcer magnitude itself can serve a discriminative function within an irregular sequence of two magnitudes. When a small reinforcer has been re-

ceived, the *average* magnitude of the next one, of necessity, must be larger (i.e., $[\text{small} + \text{large}]/2$). By the same token, average magnitude following a large reinforcer must be smaller. It readily follows that small reinforcers would control more prompt responding than large ones because small reinforcers signal a local increase in reinforcement.

It is apparent that a case can be made for dropping the inhibitory factor in favor of an account couched strictly in terms of excitatory control by stimuli correlated with the upcoming reinforcer (Shull, 1979), that is, control by stimulus properties of the past reinforcer or control by stimuli included within the schedule. The advantages of this approach (parsimony, decreased reliance on hypothetical processes) are balanced by some limitations. Although inferences about inhibition are avoided, assumptions about the subject's sensitivity to molar properties of the schedule (the average magnitude) introduce a different set of inferences. Moreover, it has become an acceptable, if not desirable, practice since Skinner's writings to include an inhibitory component in the analysis of behavioral processes (e.g., inhibitory stimulus control).

The timeout effects also may be problematic. Mazur and Hyslop (1982) treated the timeout procedure as a multiple FR extinction schedule, in which case the shortened pauses in the FR component might reflect positive behavioral contrast rather than dissipation of inhibitory aftereffects. Behavioral contrast has not been the most reliable phenomenon in rats, however (Schwartz & Gamzu, 1977; but see Williams', 1983, subsequent review). Another doubt concerns the fit of the pause-timeout relationships to what is known about contrast. Williams (1983) concluded that response rates in the reinforced component of a multiple schedule increase as a direct function of the duration of the extinction component, whereas most of the change in the present study occurred within the first 10 s of the timeout period. On the other hand, the fit of the present data to what is known about inhibitory aftereffects of reinforcers (Harzem & Harzem, 1981) may not be much better.

Finally, the present results are a step toward clarification of the relation of PR schedules to other schedules containing ratio contingencies. As discussed above, the outcomes were remarkably comparable to those from experi-

ments using fixed and variable ratios. Given the complex features of the PR schedule, it is not surprising that a comprehensive account of the variables controlling performance remains to be accomplished. Responding at each of the increasing series of ratios is subject to control by the preceding sequences, and the animal's daily behavior runs the gamut from strong control by the ratio contingency at the start to extinction at the end. Nevertheless, the orderliness of the present results recommends the PR schedule as an efficient way to approach issues ordinarily studied with ratio schedules, particularly when concern is with interactions between an experimental variable and variations in the size of the ratio.

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